Chapter 47
Autonomic Computing in a Biomimetic Algorithm for Robots Dedicated to Rehabilitation of Ankle

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ABSTRACT

Human mobility is the key element of everyday life, its reduction or loss deeply affects daily activities. In assisted rehabilitation, robotic devices have focuses on the biomechanics of motor control. However, biomechanics does not study the neurological and physiological processes related to normal gait. Biomimetics combined with biomechanics, can generate a more efficient stimulation of the motor cortex and the locomotor system. The highest efficiency obtained through torque generation models, based on the physiological response of muscles and bones to reaction forces, together with control techniques based on autonomic computation. An autonomic control algorithm has a self-adjusting behaviour, ensuring patient safety and robot operation without the continuous monitoring of the physiotherapist. Thus, this work will identify the elements that characterize the physiological stimuli related to normal human gait, focusing on the ankle joint, aiming the development of biomimetic algorithms for robots for rehabilitation of the lower limbs.

INTRODUCTION

The processes in the human gait are composed of motor control actions, position feedback and strength (Lee, 2016). However, one should not think of the human gait as a mechanical event devoid of a physiological response. It is important to have in mind that the locomotor system consists of living elements,

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such as bone and various muscle groups. A stair climb generates several foot support reactions on the rungs, which submits bones structure to tensions that change along the way. Therefore, use biomimetics techniques in robots' development, seeks to produce robots that are more efficient (Ferreira, 2015). Because they will have puts into your project specific characteristics of living organisms (Habib, 2007). These features may be related to the morphology or physiology, characterizing a physiological response to physical stimuli.

The rehabilitation techniques explore this physiological response (Jonas, 2011), which focuses on the reactivation of the motor cortex. Reactivation of the motor cortex is the restoration of a neural representation of proprioceptive elements (Zihihao, 2014), connected to each joint and muscle, this representation is called cortical map (Bueno, 2008). With regard to bone tissue, his structure is constantly changing by the action of osteocytes. The bones on skeletal system subjected to stresses have bone mass gain, in the absence of efforts they have reduction of bone mass (Turner, 2013). The physiological aspects must be considered, in torque control increasing the recovery not only of muscles but also of bone mass.

The physiotherapist estimates regarding torque control in a robot for rehabilitation, the effort made quantitatively, however the detection of fatigue performed by observing the patient's reactions (Kelln, 2008). A traditional controller based on a proportional, integral and derivative type (PID), depending on the set-point value entered as a parameter. Since the dynamic processes of biological organisms are not limited only by quantitative parameters, a PID control algorithm would not be able to detect responses such as patient fatigue, due to error behavior (Kudlack, 2016).

Autonomic computing has its origin in the study of the characteristics of the autonomic nervous system (Grupta, 2014), such as self-regulation and self-diagnosis. The introduction of these elements into an algorithm makes the system more stable, besides providing a control action that can respond to quantitative and qualitative parameters. Autonomic computing can be understood as a bio-inspired approach (Ahuja, 2014), thus Biomimetics. A biomimetic algorithm with autonomic control elements is able to produce control actions that respect the dynamic behavior of the locomotor and nervous systems. In the following sections, will be studied the aspects related to biomimetics, applied to the development of a control algorithm for a robot dedicated to ankle rehabilitation. The proposed algorithm will be able to generate stimuli with physiological character, besides having an autonomic controller, capable of responding to somatic reactions such as fatigue.

BIOMIMETICS APPLIED TO KINEMATIC MODEL FOR LOWER LIMBS

The biomimetic point of view is important to understand the physical and physiological phenomena involved, aiming to create an effective physiological response in rehabilitation. Understand aspects of the movement of the joints and reaction forces, your behavior over bone tissue, are points needed to develop a robot dedicated to rehabilitation (Bai, 2015). In this analysis, the starting point is to ensure the re-production of the ankle joint moves. Therefore, the robot must provide with only one degree of freedom, allowing the reproduction of flexion plantar and dorsiflexion (Ahmad, 2013) as shown in Figure 1.

The angles shown in Figure 1 related to the maximum displacement of the ankle joint. Dorsiflexion is the movement, which gives the gear cadence while plantar flexion is responsible for generating impulse at the beginning of travel. This way the definition of an efficient and accurate kinematic model from the computational point of view becomes important (Schmidt, 2004), this being shown by the Equation 1.